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DISINFECTANT CHEMICAL USE IN DOMESTIC WATER AND WASTEWATER TREATMENT IN THE ATLANTIC REGION IN 1990

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DISINFECTANT CHEMICAL USE IN DOMESTIC WATER AND WASTEWATER TREATMENT IN THE ATLANTIC REGION IN 1990

by

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ABSTRACT

From May to August of 1990, questionnaires were distributed to all known domestic water and wastewater treatment plants in the Atlantic Region. Responses indicated that 58% of treatment facilities in the Atlantic Region use some form of chlorine as a disinfectant. Two facilities indicated that they use ultraviolet light, and all others indicated only primary or secondary treatment, with no disinfection process.

Chlorine gas was found to be the most commonly used disinfectant. This study indicated that approximately 672,000 kg of chlorine gas are used in the treatment of wastewater and 596,600 kg are used in the disinfection of potable water each year in the Atlantic Region. Of the four Atlantic provinces, Nova Scotia was found to be the greatest user of water treatment biocides, followed by Newfoundland, New Brunswick and Prince Edward Island.

Sodium hypochlorite and calcium hypochlorite products were used to a lesser extent than chlorine gas. A total of 8,800 kg calcium hypochlorite and 38,200 L sodium hypochlorite were used per year, compared with 1,316,000 kg chlorine gas per year. All sodium and calcium hypochlorite products reported are registered pest control products, as defined by Agricuture Canada's Pest Control Products Act. Chlorine gas, however, is not registered by Agriculture Canada.

RÉSUMÉ

Entre mai et août 1990, des questionnaires ont été distribués à toutes les stations d'épuration des eaux usées d'origine domestique et industrielle au Canada atlantique. D'après les résultats, 58 p. 100 de ces stations utilisent une forme quelconque de chlore comme désinfectant. Deux stations ont indiqué qu'elles emploient les rayons ultraviolets et toutes les autres ont recours au traitement primaire et au traitement secondaire sans processus de désinfection.

Les résultats révèlent que le chlore gazeux est le désinfectant utilisé le plus souvent. En effet, chaque année au Canada atlantique, environ 672 000 kg de chlore gazeux sont utilisés pour l'épuration des eaux usées et 596 600 kg pour la désinfection de l'eau potable. Des quatre provinces de l'Atlantique, c'est la Nouvelle-Écosse qui est le plus important usager de biocides de traitement des eaux, suivie de Terre-Neuve, du Nouveau-Brunswick et de l'Île-du-Prince-Édouard.

On a constaté que les produits d'hypochlorite de sodium et d'hypochlorite de calcium sont moins utilisés que le chlore gazeux. Chque année, 8 800 kg d'hypochlorite de calcium et 38 200 L d'hypochlorite de sodium sont utilisés, comparativement à L 316 000 kg de chlore gazeux. Tous les produits d'hypochlorite de sodium et d'hypochlorite de calcium mentionnés dans le questionnaire sont des produits antiparasitaires homologués conformément à la Loi sur les produits antiparasitaires qui est administrée par Agriculture Canada. Le chlore gazeux, par contre, n'est pas homologué par Agriculture Canada.

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1.0 INTRODUCTION

In 1903, Allen Hazen determined the role that chemically treated water could play in reducing the death rate of the human population. Since that time, disinfection of potable and waste water has become widespread. The addition of chlorine compounds is one of the most widely used means of disinfection. Chlorine, as well as being an effective bactericide, has other benefits which include colour removal, taste and odour control, supression of algal growth and precipitation of iron and manganese (Task Force on Water Quality Guidelines, 1987).

In recent years there has been increasing concern about the addition of chemical disinfectants to water. Overchlorination is common as plant operators strive to ensure the cleanliness of treated water (Water Pollution Control Directorate, 1978). This is especially prevalent at treatment plants that are not functioning properly, either through age and mechanical breakdown, through overloading, or through general neglect. Where the treatment process itself is insufficient, chlorine may be heavily relied upon to remove pathogens from the water.

Unfortunately, in addition to killing pathogenic microorganisms chlorine can have a detrimental effect on aquatic biota in receiving environments. Chlorine and its various compounds do not remain in their original form when added to water. Reactions with various precursors in the water can lead to numerous compounds in the effluent, many of which may be highly toxic. One such example is chloroform, which is a proven carcinogen. Others are trihalomethanes such as bromoform and chlorodibromomethane, which are classified as suspect carcinogens (Pierce, 1978).

The exposure of receiving environments and human consumers to disinfectant-introduced contaminants in water is a function of the type and amounts of chemicals used, and the amount of time that transpires between treatment and consumption or release.

The purpose of this survey was to determine the use pattern of water and wastewater biocides in the Atlantic Region, including types of facilities, types and quantities of biocide used, and quality of the effluent.

2.0 METHODS

The method of data collection was by a questionnaire return from water and wastewater treatment facilities. That was followed up with telephone interviews and personal visits to clarify responses to the questionnaires. It was also determined, by the use of a telephone sub-sample, whether the use pattern for those who did not respond was proportional to that reported in returned questionnaires.

The questionaire was designed to cover all basic areas of interest including type of treatment, chemicals used, quantity of chemicals, chemical residence time and residual concentration in effluent. The questionnaire was fairly short and simple, with the intention that it would be applicable to all or most treatment facilities. A copy of the questionnaire is found in the Appendix.

A mailing list for water and wastewater treatment facilities in the Atlantic Region was developed with the help of the Departments of the Environment of Nova Scotia, New Brunswick, Newfoundland and Prince Edward Island. A 1986 update of the National Inventory of Municipal Waterworks and Wastewater Systems in Canada was used as a supplement in cases where other sources were incomplete.

When questionnaires were sent out, it was requested that responses be made within three weeks. Many questionnaires which were not completed satisfactorily at that time were followed up by telephone interviews with plant operators. A few plant operators provided verbal answers by telephone, especially in cases where parts of the questionnaire were not clearly understood. Personal interviews were conducted at a total of twenty eight water and wastewater treatment facilities in the four provinces. Attempts were

made to visit primarily those facilities which used some form of chlorine for water treatment. Some visits were made to facilities that did not fill out the questionnaire satisfactorily or did not reply at all. In those cases, it usually was not known before arrival at the plant whether chemicals were used or not. Because of the large number of unreturned questionnaires, a number of random phone calls were made to determine if chemicals used by those who did not respond were proportional to those from the returned questionnaires. Five percent of the total number of treatment plants in each province were involved in that survey.

3.0 RESULTS

3.1 Treatment Type and Response Rate

Table 1 indicates the total number of water and wastewater treatment plants on the mailing list, as well as the response rate from each province. Nova Scotia, Prince Edward Island and New Brunswisk have greater proportions of wastewater treatment facilities than water supply facilities.

The response rate for the survey was judged to be good, averaging 31.9% for the four provinces. The highest response rate was from Nova Scotia (43.1%) and the lowest was from Newfoundland (18.7%). Of the 343 total responses, 194 (56.6%) were from wastewater treatment facilities, 102 (29.7%) were from water treatment facilities and 47 (13.7%) indicated that facilities were no longer in use (or never existed). The proportions of each type of treatment for each province are comparable to those of the original mailing list (Table 1), with the exception of the inclusion of those with no treatment facilites.

3.2 Biocide Use

The survey revealed that three types of chemicals were used for disinfection of water and wastewater in the Atlantic Region. They were chlorine gas, calcium hypochlorite and sodium hypochlorite.

Chlorine gas was found to be the most commonly used disinfectant in the Atlantic Region. It is distributed as a highly compressed gas in 68 kg and 909 kg cylinders, with a chlorine concentration of 100%.

Table 1. Number of domestic wastewater and water supply facilities in the Atlantic Provinces which received questionnaires and the frequency of responses to questionnaires.

	N.S.	Nfld.	P.E.I.	N.B.
Total	406	337	36	341
Wastewater Facilities	336	116	25	269
Water Supply Facilities	70	221	11	72
Total Responses	175	63	14	91
Percent Responses	43.1	18.7	38.9	26.7
Reported Wastewater	118	12	9	55
Reported Water Supply	36	38	3	25
No Treatment Facility	21	13	2	11

Calcium hypochlorite and sodium hypochlorite are the active ingredients in a large number of registered Pest Control Products. A total of three calcium hypochlorite products and five sodium hypochlorite products were reported to be used in the Atlantic provinces for water and wastewater treatment.

Sodium hypochlorite is distributed in a liquid form, with most products having an active ingredient concentration of approximately 10%. The calcium hypochlorite products are distributed in a solid form (usually granular or as pucks or tablets), which have an active ingredient concentration of 65% to 70%.

There were two reports of the use of ultraviolet light for wastewater treatment in Nova Scotia. This non-chemical method of disinfection has been proven to be highly effective (Water Pollution Control Directorate, 1978). The greatest benefit of such disinfection is the lack of toxic residual compounds in the effluent. The major disadvantage is that present systems cannot be easily converted for this process.

Table 2 indicates the number of questionnaire responses that reported the use of each chemical disinfectant. Trade names and Pest Control Product Numbers are included.

Table 3 indicates the total numbers and percent of treatment facilities from each province and from the Atlantic Region that reported the use of chlorine products for disinfection.

Because such a large proportion did not respond to the questionnaire, 5% of the total number of water and wastewater facilities were phoned at random to determine how many of these used chemical disifectants. The results of those telephone interviews are listed in Table 4, according to the type of treatment for each province. A regional average of 28.6% use some form of chlorine compound for water or wastewater disinfection. There were three cases (one in Newfoundland and two in New Brunswick) in which facilities contacted in the telephone survey were among those that had submitted a questionnaire. These three were omitted from the telephone survey results to avoid replication of data.

Table 2. Trade names, PCP numbers, and number of treatment facilities reporting the use of each product.

	Trade Name	PCP #	No. of Reports				
			NS	NFLD	PEI	NB	Total
Calcium Hypochlorite	Calcium Hypochlorite 65%	17949	9	6	0	1	16
	Jet Chlor	20462	7	2	0	2	11
	Sanuril 115	14775	15	0	0	3	18
Sodium Hypochlorite	Sodium Hypochlorite	16575	6	1	0	0	7
	Lavo 12	12419	2	0	0	1	3
	Javex 12	21159	0	1	0	0	1
	Dibac	16204	0	3	0	0	3
	x-4 Chlorine Bleach	12181	0	1	0	0	1

Table 3. Number and percent of treatment facilities that reported the use of chlorine products.

	N.S.	Nfld.	P.E.I.	N.B.	Regional Total
Total no. responses	175	63	14	91	343
No chemical treatment	47 (27%)	18 (28%)	12 (86%)	65 (71%)	142 (42%)
Cl Gas	64 (37%)	30 (48%)	2 (14%)	15 (16%)	111 (32%)
Na Hypochlorite	25 (14%)	9 (14%)	0 (0%)	5 (6%)	39 (11%)
Ca Hypochlorite	39 (22%)	6 (10%)	0 (0%)	6 (7%)	51 (15%)

Table 4. Biocide use for treatment facilities responding to telephone enquiries.

	N.S.	Nfld.	P.E.I.	N.B.	Regional Total
Total	406	337	36	341	1120
No. contacted	20	16	2	15	53
No chemical treatment	12 (60%)	9 (56%)	2 (100%)	8 (53%)	31 (58%)
Cl Gas	8 (40%)	5 (31%)	0 (0%)	5 (33%)	18 (34%)
Na Hypochlorite	0 (0%)	0 (0%)	0 (0%)	1 (7%)	1 (2%)
Ca Hypochlorite	0 (0%)	2 (13%)	0 (0%)	1 (7%)	3 (6%)

In many cases the information on biocide use obtained from the telephone enquiries differed markedly from estimates obtained from the questionnaire return. This indicated that a direct extrapolation to calculate biocide use patterns from questionnaire responses would not be accurate.

Table 5 shows the quantities of biocide used in the Atlantic Region, as reported in questionnaires, as well as an estimated total extrapolated using proportions indicated in the telephone survey. The total quantity of each biocide used in each province, as reported in returned questionnaires, was first divided by the number of facilities reporting the use of that biocide to derive the quantity of biocide used per facility.

The telephone survey was conducted to determine the percentage of non-responding facilities which did in fact use biocide. Using the estimate of biocide used per facility from questionnaire responses, a total quantity of biocide used at non-responding facilities was derived and added to the questionnaire results.

This number was then added to the total quantity of biocide used in each province as reported in questionnaires, to obtain a total quantity of biocide used in all treatment facilities in each province.

Table 5. Quantities of biocide reported in questionnaires and extrapolated totals from telephone survey.

	N.S.	Nfld.	P.E.I.	N.B.	Regional Total
Chlorine Gas					
Total from questionnaires	241 900	111 700	32 900	33 400	419 900
Extrapolated totals	591 100	427 900	32 900	217 100	1 269 000
Na Hypochlorite					
Total from questionnaires	11 500	2 800	0	5 300	19 600
Extrapolated totals	11 500	2 800	0	23 900	38 200
Ca Hypochlorite					
Total from questionnaires	1 500	600	0	800	2 900
Extrapolated totals	1 500	4 200	0	3 100	8 800

Table 6 indicates the total amount of each chemical used for water and wastewater treatment in each of the four provinces per year, and the total quantities of each for the Atlantic Region.

Table 6. Total biocide use for water and wastewater treatment in the Atlantic Region.

	N.S.	Nfld.	P.E.I.	N.B.	Regional Total
Chlorine Gas (kg/year)					
wastewater	336 900	205 400	32 900	86 800	672 600
water supply	254 200	222 500	0	130 300	596 400
Na Hypochlorite (L/year)					
wastewater	2 100	0	0	23 900	13 000
water supply	9 400	2 800	0	0	25 200
Ca Hypochlorite (kg/year)					
wastewater	2 700	0	0	3 100	6 600
water supply	0	4 200	0	0	2 200

The data indicated that biocides were generally mixed to obtain a chlorine nominal concentrate of 5 mg/L, however, rates varied between 0.2 and 5.5 mg/L of chlorine. Those rates, which were calculated by dividing the total chorine used by the amount of water treated, indicated the concentration of chlorine at the point of addition, and they were not necessarily indicative of the concentration of chlorine in the effluent. Table 7 summarizes those quantites and indicates regional averages.

Table 7. Average calculated concentrations of chlorine in treated water for the Atlantic Region.

	Calculated Chlorine Concentration (mg/L)				
	N.S.	Nfld.	P.E.I.	N.B.	Regional Average
Chlorine Gas	4.10	4.05	5.52	2.36	4.01
Calcium Hypochlorite	0.25	1.6	N/A	0.16	0.50
Sodium Hypochlorite	1.4	1.1	N/A	0.72	0.55

3.3 Chemical Residence Time

One factor which can have a strong influence on the effectiveness of a chemical disinfectant is the length of time that disinfectant is kept in contact with the water to be treated. This length of time is referred to as the chemical residence time. Table 8 shows the average residence times for disinfectants in the Atlantic provinces.

Table 8. Sample sizes and average residence times for chemical disinfectants in the Atlantic Region.

	N.S.	Nfld.	P.E.I.	N.B.	Atlantic Region
Number in Sample	57	10	1	4	72
Residence Time (minutes)	22	35	20	25	26

3.4 Residual Concentrations in Effluents

The concentrations of residual measured chlorine reported were relatively consistent, with a mean, a median and a mode of 0.5 mg/L. The average concentrations of chlorine residual reported for each province are listed in Table 9.

Table 9. Average concentrations of chlorine residual for water and wastewater treatment facilities in the Atlantic Region.

	Chlorine Residual (mg/L)				
	N.S.	Nfld.	P.E.I.	N.B.	Regional
Water Supply	0.84	0.26	0.00	0.58	0.42
Wastewater	0.58	0.64	0.25	0.40	0.47

3.5 On Site Visits

A total of 28 treatment facilities were visited to determine the accuracy of questionnaire responses. Below is a list of the facilities visited in all four Atlantic Provinces.

Nova Scotia

Chester
Western Shore
New Germany
Milton
Digby
Bridgetown

New Brunswick

Buctouche
Shediac
Sussex
Balmoral
Eel River Crossing
Bathurst
Douglastown

P.E.I.

Miscouche
Kensington
Kinkora
Borden
Charlottetown
Wellington

Newfoundland

Portugal Cove
Conception Bay South
Whitbourne
Terrenceville
Gander (1)
Gander (2)
Gambo
Holyrood

A number of these facilities were having operational difficulties due to the lack of rain in the summer of 1990. This caused a decreased use of chlorine due to the decreased volume of water passing through the system and a decreased volume of the receiving water. Facilities that were affected by the lack of rain were Western Shore, Chester, New Germany and Whitbourne.

4.0 DISCUSSION

Three chemicals were found to be used in both water and wastewater treatment in the Atlantic Region. These were chlorine gas, calcium hypochlorite, and sodium hypochlorite. The calcium hypochlorite products included Calcium Hypochlorite 65%, Jet Chlor, and Sanuril 115 and the sodium hypochlorite products included Sodium Hypochlorite, Lavo 12, Javex 12, Dibac and x-4 Chlorine Bleach.

A total of 1120 questionnaires were sent out to water and wastewater treatment facilities across the Atlantic Region, and 343 (31.9%) were returned. Of the total responses, 194 (56.6%) were from wastewater treatment facilities, 102 (29.7%) were from water treatment facilities, and 47 (13.7%) indicated that facilities were not active.

A telephone survey was conducted to determine the proportion of those who did not respond to the questionnaire that used chemical disinfectants. It was found that the proportion of facilities using chemicals was lower for those who did not respond to the questionnaire. The total quantity of each biocide used in each province, then, was calculated by extrapolating values received on questionnaires together with proportions collected from the telephone survey. Through these calculations it was estimated that 1 269 000 kg of chlorine gas are used for water and wastewater treatment in the Atlantic Region every year. Of this, 596 400 kg (47%) are used in the disinfection of potable water and 672 600 Kg (53%) are used in the treatment of wastewater. All four provinces used more chlorine gas than any of the other two products. Calcium hypochlorite was used the least. That is probably due to the fact that chlorine gas is the least costly form of chlorine that can be used in large facilities. Sodium and

calcium hypochlorite have generally been used in small systems where safety concerns related to handling chlorine gas outweigh economic benefits (U.S. EPA Technology Transfer, No Date).

Calcium and sodium hypochlorite products are registered under the Canadian Pest Control Products Act. Chlorine gas, which was found to be used in the greatest quantities of the three, is not a registered Pest Control Product. The Pest Control Products Act defines a control product as any "product, device, organism, substance or thing that is manufactured, represented, sold or used as a means for directly or indirectly controlling, preventing, destroying, mitigating, attracting or repelling any pest...". Section 6 of the Pest Control Products Regulations specifies that all control products must be registered for use by Agriculture Canada, unless they are exempt (Section 5). Chlorine gas is used for the control of various bacteriological and viral pests in both water supply and wastewater systems. Consideration should therefore be given to registering such products under the Pest Control Products Act.

Standards for wastewater disinfection generally specify the maintenance of a chlorine residual in the range of 0.5 to 1.0 mg/L after a 15 to 30 minute contact time (Water Pollution Control Directorate, 1978; Environment Canada EPS, 1976). The average residence time for the Atlantic Provinces is 26 minutes, which is lower than the 30-minute minimum recommended for federal facilities (Environment Canada EPS, 1976) but within the recommended range of 20 - 30 minutes for most other areas (Water Pollution Control Directorate, 1978).

Residual chlorine concentrations in effluents were relatively consistent, with a mean, a median and a mode of 0.5 mg/L. Prince Edward Island reported the lowest residual concentrations (0.25 mg/L) while Newfoundland reported the highest (0.64 mg/L). The recommended concentration of residual chlorine for disinfection is 0.5 mg/L, with a maximum of 1.0 mg/L. That concentration is well below those known to have physiological effects in mammals (Water Pollution Control Directorate, 1978). The concentration of chlorine producing

toxicity to aquatic, estuarine and marine organisms, however, is much higher than that for humans. Acute LC50's as low as 0.02 mg/L for aquatic invertebrates have been reported (Task Force on Canadian Water Quality Guidelines, 1987).

Those individuals whos primary concern is the well-being of aquatic ecosystems suggest that residual chlorine levels be kept as low as possible. On the other hand, those persons concerned primarily with public health insist that the risk to human safety can be lessened greatly by the addition of adequate amounts of disinfectant. A common practise is to over-chlorinate to ensure, from a public health point of view, the adequacy of disinfection. This often results in the discharge of excessively high levels of chlorine (Water Pollution Control Directorate, 1978).

As a comparison of the values presented in Tables 7 and 9 indicate, the quantity of biocide added does not necessarily reflect what the residual concentration in the outfall will be. In fact, this study indicates there is often a difference of a factor of 10 between those two values. The variation between the concentration of chlorine added and the concentration of residual in the effluent can be affected by many factors. One is a variation in the distance from the treatment area to the actual outfall area. The longer the distance, the lower the concentration of residual chlorine. Increasing distance acts to extend the chemical residence time, which allows for an additional decrease in chlorine concentrations. Some plant operators measure the residual chlorine concentration immediately as the effluent leaves the treatment area while some measure it where the effluent meets the receiving water. Dosage changes may be necessary from one season to another, or even from day to day, to keep the residual level at a constant 0.5 mg/L. In practise this is very difficult as residual levels in most facilities are constantly fluctuating. Although the concentration of residual chlorine decreases sharply with distance from the effluent outfall, the residual concentration of chlorine may remain elevated for more than two days depending upon water quality characteristics (Water Pollution Control Directorate, 1978). Dispersal of effluent into the receiving water, then, must be quite rapid in order to prevent elevated chlorine concentration at the outfall site.

This study has revealed that, although chemical disinfectants are used for the most part within recommended guidelines, there may still be some cause for concern. The use of these products must be controlled in order to prevent excessive or improper use which could cause harm to the surrounding environment.

5.0 RECOMMENDATIONS

1. Environmental Protection should undertake sampling of effluents of various water and wastewater treatment facilities to determine whether the residual chlorine is, in fact at the recommended concentration of 0.5 mg/L.

2. Chlorine gas should be assessed for registration by Agriculture Canada as a pest control product as defined by the Pest Control Products Act.

3. The use patterns of chlorine gas should be further investigated.

4. Provincial and federal environment departments should measure the impact of chlorine on receiving environments.

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APPENDIX

WATER/WASTEWATER TREATMENT QUESTIONNAIRE

1. Location/Name of Facility: _____

   Owner: _____

   Contact Name: _____

   Telephone #: _____

   Mailing Address: _____

   _____

   _____

2. Type of Treatment: _____

3. Flow (L/day): _____

4.

Chemical Name (active ingredient)	PCP #	Volume of Chemical/ Unit Water Treated	Chemical Residence Time (minutes)	Residual Concentration	Residual Frequency of Measurements	Chemical Application Period (months)

5. Release Point (Receiving Water): _____

6. Chemical Supplier: _____

7. Flow Schematic of Process:
(may be hand-sketched)